Study of Rice Straw Biocomposite and a Comparative Study of Flexural Strength of Various Biocomposite Plywood Materials

Swadesh Kumar Singh, Jandhyala N Murthy, PAPN Varma, and D Sailaja

Abstract—Green building is a movement that has gained the global attention over the past few years. Green buildings are planned to be environmentally responsible, economically viable and healthy places to live and work. One of the main materials currently used in green buildings is biocomposite. In the present work detailed study for the rice straw biocomposite is performed and a comparison of flexural strength is made between different biocomposites. Some of the biocomposites used in the present research are sugarcane bagasse plywood, particulate plywood composite, pure teak wood and plywood manufactured by different layers of nu-wood.

Keywords—Green Building; Biocomposite; Rice Husk Biocomposite; Plywood.

I. INTRODUCTION

A BIOCOMPOSITE is a material formed by a matrix (resin) and a reinforcement of natural fibres (usually derived from plants or cellulose). (consider this as components is too vague). Biocomposites are made of two or more components mixed together to form complex substances with new dimensions of properties. In recent times there has been an increasing demand for developing composite substances using natural and synthetic components which may be used for building and construction purposes like partition boards, preframed roofing, plywoods and flooring materials with low cost and high durability. The raw materials used for this purpose if they are derived from natural renewable resources or environmental wastes or industrial wastes then such biocomposites would be cheaper and available even to a common man. Keeping such demand in view, present study is aimed to have review and experimentation on certain biocomposite materials using various natural biowaste resources mixed in various combinations reinforced in synthetic resins like urea formaldehyde, phenol formaldehyde, tannins etc. for various building purposes depending on their strength.

According to their manufacturing processes, wood-based boards are classified into wet process fibreboards (fibre distribution takes place in water) and dry process fibreboards (fibre distribution takes place in air). Wet process boards are classified according to their density into hardboards and medium boards [1]. Medium density fibreboard is a generic term for a panel primarily composed of lignocellulosic fibres combined with a synthetic resin or other suitable bonding system and bonded together under heat and pressure. The panels are compressed to a density of 500-800kg/m³. Additives may be introduced during manufacturing to improve certain properties. Because fibreboard can be cut into a wide range of sizes and shapes, applications are many, including industrial packaging, displays, exhibits, toys and games, furniture and cabinets, wall paneling, molding and door parts. Few techniques usually applied to produce fibreboards are thermomechanical pulping and chemithermomechanical pulping. The fibre separation is achieved by using grinding or refining or a combination of them. Grinding involves the pressing of wood logs against a revolving pulp-stone, while in refining wood chips are disintegrated in a revolving disc refiner. As a result, wood fibres are fractured and the resulting pulp is consisting of fibres of various lengths, fibre fragments and shives [2].

Nowadays, there are several potential applications for medium density fibreboards in many fields and the rate of manufacturing is increasing across the world. The cabinet doors, shelves, laminated floors, furniture, panels for building construction are typical products of medium density fibreboards. The commonly used method, for producing medium density fibreboards and high density fibreboards, employs wood-based raw materials (softwood and hardwood). The majority of wood raw materials are mainly utilized for sawn lumber products and in the pulp and paper industry. Therefore, demand for non-wood lignocellulosic fibre resources is also increasing, due to the lack of wood raw materials and for environmental and economic considerations. Currently the most commonly used non-wood materials are bamboo, hemp, jute, kenaf and bagasse as well as cereal straws (rice and wheat straw).

In biocomposite materials fibres are woven into mats and mats are dipped in synthetic resins to develop structural frames called fibreboards. The synthetic resins act like filler and give strength to the biocomposite material. In some biocomposite combinations where the lignin concentration is high, additional adhesive binders may not be required as lignin under heat and pressure flow act as thermosetting
fibres have relatively similar compositions as other natural
characteristics [1]. Chemically, lignocellulosic rice straw
composites. This is because of their lignocellulosic
and complex morphology structure of rice straw, its fibres
present work. Medium density fibreboards has provided a motivation for the
pulverizing the wax layer and producing rice straw based
as a raw material for producing fibreboards. The problem of
directed many researches and manufacturers to wheat straw
based fibreboards and makes rice straw impractical. This has
as a technical problem for the production of the rice straw
water-based adhesives. Removing this wax layer is considered
gluing of the straw or acts as a barrier for the absorbance of
wax layer obstacles the penetration of the adhesive and proper
that covers the epidermal cells/outermost surface cells. This
fibrous residue of sugarcane after crushing and extraction of its juice, known as
‘bagasse’, is one of the largest agriculture residues in the
world. An analysis of sugarcane bagasse indicates that its
main constituents are cellulose, hemicellulose, lignin, ash and wax. Both sugar cane cornrod and their mixture with
hardwood are used with phenol formaldehyde resin and wax
to manufacture composite board.

Wetting of untreated straw and applying water based
adhesive to the chopped straw is considered as a technical
challenging point due to the presence of the thin wax layer
that covers the epidermal cells/outermost surface cells. This
wax layer obstacles the penetration of the adhesive and proper
 gluing of the straw or acts as a barrier for the absorbance of
water-based adhesives. Removing this wax layer is considered
as a technical problem for the production of the rice straw
based fibreboards and makes rice straw impractical. This has
directed many researches and manufacturers to wheat straw
as a raw material for producing fibreboards. The problem of
pulverizing the wax layer and producing rice straw based
medium density fibreboards has provided a motivation for the
present work.

<table>
<thead>
<tr>
<th>Material</th>
<th>Wax</th>
<th>Hemicellulose</th>
<th>Cellulose</th>
<th>Lignin</th>
<th>Ash</th>
<th>Silica</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice straw</td>
<td>3.72</td>
<td>35.5</td>
<td>39.63</td>
<td>13.92</td>
<td>12.51</td>
<td>9.68</td>
</tr>
<tr>
<td>Sugarcane bagasse</td>
<td>0.95</td>
<td>29</td>
<td>51</td>
<td>15</td>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Spruce wood</td>
<td>1.47</td>
<td>23.4</td>
<td>54.09</td>
<td>30.15</td>
<td>0.24</td>
<td>-</td>
</tr>
</tbody>
</table>

Though, the chemical composition, heterogeneous structure
and complex morphology structure of rice straw, its fibres
have a potential application for manufacturing of fibre
composites. This is because of their lignocellulosic characteristics [1]. Chemically, lignocellulosic rice straw
fibres have relatively similar compositions as other natural
fibres (fibres of wood, flax, jute, sisal, etc.) that are used in
fibreboard manufacturing [6]. The most important benefits of
selecting the rice straw (which is agricultural residue and
grown in large areas of the world) material for medium
density fibreboards production are reduction of open field
burning of an annual plant and to capture carbon dioxide. In
addition, the straw based medium density fibreboard panels
can be recycled or converted to energy after utilization.

Bonding agents are those conventionally employed in
forming composite products and include both acidic and
alkaline type binders. Typical bonding agents are amino
resins, phenolic resins, resorcinol resins, tannin resins,
isoxyanate adhesives or mixtures thereof. Resins which can be
used to bond treated straw fibres include urea–formaldehyde
resins [1], melamine urea-formaldehyde resins, phenol-
formaldehyde [7], resorcinol–formaldehyde, tannin-
formaldehyde, polymeric isocyanate[8] and mixture thereof.
The resins can be added in different amounts based on several
parameters. Since there are many options to make these
plyboards used in primarily household construction, the
bending strength comparison is made in the present paper to
select appropriate composite for a particular application.

II. EXPERIMENTATION

Sugarcane plywood, particulate plywood composite, pure
teak wood and plywood manufactured by different layers of
waste wood were taken and the samples for the bend test were
cut into appropriate sizes. The experimental test rig can be
seen in Figure 1. Since there are fibres in most of these
composites and there will be transgranular cleavage fracture
in most of these composites, so very slow cross head speeds
were selected for the test (0.3 mm per min). Data were
recorded for every 2 mm advancement of the bending tool. 3
samples were tested in the similar setup and the average of
the data is taken for the analysis. Figure 2 shows the fracture
in the material at a certain load and the maximum load at
which this fracture appears is noted down. Table-II shows the
parameters of various composites used in the experimental.
Flexural strength, also known as modulus of rupture, bend
strength or fracture strength, a mechanical parameter for
brittle material like plywood, is defined as material’s ability
to resist deformation under load. The transverse bending test
(as discussed in this article) is most frequently employed, in
which a rod specimen having either a circular or rectangular
cross-section is bent until fracture using a three point flexural
test technique. The flexural strength represents the highest
stress experienced within the material at its moment of
rupture. The modulus of rupture calculated for the various
biomaterials by experimentation is also presented in Table II.
Figure 3 presents the modulus of rupture calculated under
various densities of rice husk composite bonded with urea-
formaldehyde resins by El Kassas et al [1].

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III. RESULTS AND DISCUSSION

As it can be seen in Figure 3 that the modulus of rupture of for the rice straw biocomposite for medium density board is around 25-40 MPa and it is highly dependent on the density and also the concentration of urea-formaldehyde. From Table-II it can be seen that the modulus of rupture for teak wood is highest i.e. 63.36 MPa and it is known to be the strongest wood but this wood is not only rare but also expensive. Sugarcane bagasse ply is having rupture modulus of 18.7 MPa and this is the cheap material in the regions of the world where sugarcane grows and also these plys are subjected to fungal and other bacterial attacks over a period of time. Particulate material is the wood dust coming out of various process and its rupture strength is very low, but these materials are cheapest. The normal wood ply used in the experimentation was the mixture all the different types of wood waste including teak. That is the reason its strength in quite high, almost similar to the rice straw ply.
cause some types of cancers. So some different adhesives preferably some other biomaterial should be used in rice husk to decrease the formaldehyde pollution.

IV. CONCLUSION

Flexural strength of various biocomposites was compared in this article. Technically teak wood can provide maximum strength fibreboards, but economics of the material may force alternatives. Plywoods manufactured by rice husk promise good and almost comparable strength. Although these plywoods can also be manufactured by some other bio-waste like sugarcane bagasse but there are possible fungal infection in these material over a period of time. But the resins that bonds the rice husk should be replaced with some other bio material as the present bonding material urea-formaldehyde is cancerous.

REFERENCES


**Dr. Swadesh Kumar Singh** received his Ph. D. from IIT Delhi India and presently he is an Professor in the Department of Mechanical Engineering at GRIET, Hyderabad, India. For the bachelor’s degree, he received a gold medal for excellence in academics. Dr. Singh has been involved in research on numerical simulation and experimental studies on formability of sheet metal forming, characterization of metals and biocomposites. He is awarded young scientist award by DST, Govt of India and young teacher award by AICTE, Govt of India for his contribution in research. He has authored several international journal papers and received the sponsored project grants from various agencies. He has 74 publications in reputed International journals and conferences.

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